Extended Abstract

OMPS - The Next Generation Sensor Suite for Global Ozone Monitoring

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Abstract - The Ozone Mapping and Profiler Suite (OMPS) will collect total column and vertical profile ozone data and continue the daily global data produced by the current operational satellite monitoring systems, the Solar Backscatter Ultraviolet radiometer (SBUV/2) and the Total Ozone Mapping Spectrometer (TOMS), but with higher fidelity. The collection of this data will contribute to fulfilling US treaty obligations to monitor ozone depletion for the Montreal Protocol. OMPS has been selected to fly on the National Polar-Orbiting Operational Environmental Satellite System (NPOESS) spacecraft – the next generation of polar orbiting environmental satellites. The fist OMPS flight unit will fly on the NPOESS Preparatory Project (NPP) spacecraft.

1.0 Introduction

The OMPS sensor suite consists of a limb ozone profiling sensor, a nadir in which resides the nadir total column sensor and the nadir profiler, and the main electronics box.

Limb-scattered solar radiation is measured at selected ultraviolet (UV), visible, and near infrared (NIR) wavelengths to determine ozone profile concentrations for the altitude range of 8 to 60 km. The sensor consists of a telescope with three separate crosstrack fields of view of the limb, a prism spectrometer covering 290 to 1050 nm, and a solar-diffuser calibration mechanism. The sensor provides 3 km vertical resolution profiles of atmospheric radiance with channel spectral resolutions (full-width at half-maximum, FWHM) ranging from 3 nm in the UV to 50 nm in the NIR and handles the demanding spectral and spatial dynamic range of the limb-scattered solar radiation with the required sensitivity for ozone retrievals.

In the Nadir sensor backscattered solar ultraviolet radiation is dispersed and measured to determine the ozone total column amounts and profile concentrations. The sensor consists of a wide field (110 degree) telescope, with a solar-diffuser calibration mechanism, and two spectrometers: an imager covering 300 to 380 nm with a 50 km nadir footprint for mapping total column ozone across a 2800 km swath, and a 250 to 310 nm spectrometer with a single 250 km footprint to provide ozone profile data with SBUV/2 heritage. Both spectrometers provide 1 nm resolution (full-width at half-maximum, FWHM) spectra and handle the demanding dynamic range of the backscattered solar radiation with the required sensitivity for ozone retrievals.

2.0 Scientific Overview

Working with an algorithm team at Raytheon ITSS (formerly Hughes STX) led by Dr. Jack Larsen, Ball Aerospace derived OMPS sensor and algorithm requirements from NPOESS ozone environmental data record (EDR) performance requirements. The total column requirements dictate a sensor that will provide a completely new global map of ozone column amount within 24 hours, but with significantly improved ozone accuracy and precision[1]. Although the ozone profiling requirements are satisfied primarily by the OMPS limb sensor, it was deemed beneficial to continue the long nadir profile data record started in 1971 with the Backscatter Ultraviolet (BUV)[2] Atmospheric Ozone Experiment.

The limb sensors spectral range and channel selection were determined by detailed analysis of several science and algorithm requirements. A short wavelength limit of 290nm provides the required sensitivity at the upper end of the altitude range (60 km). Other channels in the middle and near ultraviolet provide coverage down to 28 km. Several channels in the Chappuis band including 602 nm provide coverage between 28 km and the tropopause. Additional channels between 350 and 1000 nm provide characterization of the Rayleigh and aerosol scattering background. The calibration stability essential for long-term monitoring of ozone is maintained on-orbit by periodic observations of the sun using a diffusing element to direct the solar irradiance into the telescope.

The vertical cell size requirement threshold of 5 km drove the requirements for a separate limb sensor since the inherent vertical resolution of nadir ozone profiling is 8 to 12 km using backscattered solar radiation in the ultraviolet Hartley and Huggins absorption bands[3]. In addition, the vertical coverage EDR requirement (tropopause height to 60 km) could not be satisfied by the nadir profiling technique, which provides profile information independent of a priori assumptions in the 30-50 km range[3]. Remote sensing of limb-scattered solar radiation shares atmospheric radiative transfer physics as well as calibration techniques with the OMPS nadir sensor. Early on-orbit demonstrations of limb scatter ozone profiling used measurements at 265 and 296 nm where single (Rayleigh) scattering is dominant, thereby restricting the technique to the mesosphere and upper stratosphere[4]. Because of the great scientific interest in the behavior of ozone at and below the ozone peak, Herman et al.[5] showed that profiling could be extended down to 15 km using limb scatter measurements at 602 nm, the peak of the Chappuis absorption band.

3.0 Technical Challenges

The primary technical challenge in the design of the OMPS Nadir Sensor is the wide field of view (FOV) required (110°) in order to satisfy the stringent NPOESS revisit requirement from an altitude of 833 km without the use of scan mechanisms. In addition, the mass and volume constraints for OMPS require a solution that is lightweight and compact.

The primary technical challenge in the limb sensor objectives is the large dynamic range inherent in the UV to NIR limb spectrum. The signal varies by 4 to 5 orders of magnitude across the measured spectral and vertical ranges. In addition, the precision requirements of the ozone profile retrieval demand that the sensor make measurements with high signal to noise ratios (SNR), particularly in the visible spectral channels. The wide signal range requires the use of multiple gain ranges that are provided by different aperture areas and different integration times in the OMPS Limb Sensor.

4.0 Calibration

The limb sensor's measurements are used to determine the ratio of radiances between different altitudes it is important that any change in pixel gain be known. The pixel gain is determined by rotating a solar illuminated diffuser in front of the sensor field-of-view. Two diffusers, a working diffuser and a reference diffuser, are used to reduce the effects of long-term degradation, due principally to contamination. The transmissive diffusers are attached to the solar calibration wheel and are composed of a microlens array and two rough diffuse surfaces on fused silica. Prelaunch goniometric calibration of the diffusers will characterize their scattering properties as a function of the incidence angles for which solar measurements are anticipated in orbit. To satisfy the long-term stability requirement of 0.2% change over 7 years on orbit, the working diffuser is used weekly and the reference diffuser is used once every six months, thus limiting the effects of contamination. Wavelength calibration is also performed during the solar calibration by making use of the spectral structure of the solar Fraunhofer lines.

To determine ozone abundance from the backscatter UV observations (nadir instrument), the ratio of Earth radiance to solar irradiance (referred to as the terrestrial albedo) is measured. The solar irradiance is determined by positioning a solar illuminated diffuser in front of the sensor field-of-view to produce a diffuse radiance. The measurement of the terrestrial albedo cancels out the gain of the sensor leaving the diffuser as the only sensor element not common to both measurements. Changes in both the CCD pixel dark current and the signal linearity of the on-chip output amplifier will result from exposure to radiation. For nadir and limb both of these performance parameters are measured once a week with the calibration/door rotor in the closed position during the dark part of the orbit. The total linearity measurement takes approximately 275 seconds and will provide linearity knowledge to within approximately 0.2%.

5.0 Conclusion

A high-accuracy and high-reliability nadir ozone mapping and profiling sensor and the limb ozone profiling sensor has been designed by Ball Aerospace & Technologies Corp for NPOESS as part of the OMPS contract. The limb ozone profiling sensor's staring spectrometer architecture and hyperspectral coverage eliminate the need for any continuous-action mechanisms, increasing the reliability of the sensor. The modular design is compact and athermal, requiring only passive thermal control with the exception of the CCD. The first launch of the OMPS on board the NPOESS Preparatory Platform (NPP) spacecraft is expected to launch in 2006. The first launch of the NPOESS 13:30 afternoon spacecraft, planned to carry an OMPS sensor suite, is expected after 2008.

References

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